SEVENTH JOINT MEETING
of the
SPACE RESOURCES ROUNDTABLE
and the
PLANETARY & TERRESTRIAL MINING SCIENCES SYMPOSIUM

Colorado School of Mines
Golden, Colorado, USA
June 7-9, 2016

SPACE RESOURCES ROUNDTABLE

PTMSS
Planetary & Terrestrial Mining Sciences Symposium

Message

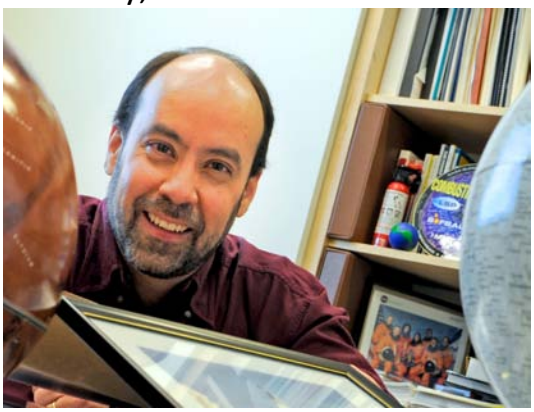
Welcome to the Seventh Joint Meeting of the Space Resources Roundtable (SRR) and the Planetary and Terrestrial Mining Sciences Symposium (PTMSS).

This is undoubtedly an exciting time for the space resources community. Not since NASA's Vision for Space Exploration (VSE) initiative in 2004, has so much attention being placed on this area. However, this time is markedly different. In contrast to the VSE, interest is coming from a variety of participants with a wider set of objectives. New studies and projects incorporating ISRU technologies are being conducted for missions to the Moon, Mars, and asteroids by space agencies around the world and the commercial space sector, while legislation has been passed for commercial space-resource exploration and utilization. Even the release of a popular movie last year highlighted the critical role of space resources in human exploration and generated much excitement in the general public around this topic. It is now sufficiently clear that the use of space resources is a critical-path activity for the exploration and commercialization of space.

This increased attention brings many unique opportunities, but also a call for greater involvement from our community. Given the realities of limited financial resources and shifting priorities in space programs worldwide, our expertise is needed to provide the necessary scientific, technical, legal, and policy guidance to move our field from the movie screen to a real component of space exploration.

We invite all meeting participants to actively contribute to this discussion and to help make the years to come even more interesting and exciting.

Sincerely,



Angel Abbud-Madrid
President & Chair, SRR XVII

Dale Boucher
Chair, PTMSS XIII

Sponsors

On behalf of the SRR and PTMSS Steering Committee, we would like to express our appreciation to this year's sponsors.

Program Schedule

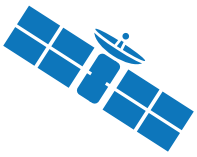
TUESDAY, JUNE 7, 2016

7:30 AM	**Continental Breakfast (Petroleum Hall, CSM Green Center)**	
8:00	Opening remarks SRR scholarships	Angel Abbud-Madrid & Dale Boucher
Technical Session 1 – MARS I		
Session Chair: Angel Abbud-Madrid (Colorado School of Mines)		
8:30	**First Landing Site-Exploration Zone for Human Missions to the Surface of Mars** Richard Davis, NASA Headquarters	
8:55	**Benefits of Mars ISRU Regolith Water Processing: a Case Study for the NASA Evolvable Mars Campaign** Julie Kleinhenz, NASA Glenn Research Center	
9:20	**Description of Water Resources on Mars that Have the Potential to Become Reserves as Part of a Human Exploration Zone: The M-WIP Study, Part 1** David Beaty, NASA Jet Propulsion Laboratory	
9:45	**Engineering Analysis of Candidate Ore Cases for ISRU Water Production on Mars: The M-WIP Study, Part 2** Paul Van Susante, Michigan Technological University	
10:10	**Engineering Sensitivities to Ore Characteristics for Water Resources on Mars and Implications for Resource Exploration Approaches: M-WIP Study, Part 3** Charles Whetsel, NASA Jet Propulsion Laboratory	
10:35	**Coffee Break**	
Technical Session 2 – MARS II		
Session Chair: David Beaty (NASA Jet Propulsion Laboratory)		
10:55	**System Maturation Team Assessment of ISRU for NASA's Evolvable Mars Campaign** Jerry Sanders, NASA Johnson Space Center	
11:20	**The Mars Oxygen ISRU Experiment (MOXIE) on the Mars 2020 Rover** Michael H. Hecht, Massachusetts Institute of Technology	
11:45	**Efficient Microwave Approaches for Extracting Water from Hydrated Minerals** Gerald Voecks, NASA Jet Propulsion Laboratory	
12:10	**Integrated Economics Model for ISRU in Support of a Mars Colony—Initial Results** Robert Shishko, NASA Jet Propulsion Laboratory	
12:35	**The Journey to Mars with ISRU Pathway** John Hamilton, PISCES, University of Hawaii, Hilo	

1:00	**Lunch (Friedhoff Hall, CSM Green Center)**
2:00 – 3:30	**Mars Roundtable Discussion** **Session Chairs: Angel Abbud-Madrid & Dale Boucher**
	Technical Session 3 - ISRU Construction and Manufacturing Technologies
	Session Chair: Sherry Schmidt (Deltion Innovations)
3:30	**Manufacturing for Planetary Construction using Polymeric Concrete** Byung Chul Chang, International Space Exploration Research Institute of Hanyang University
3:55	**Transforming Lunar Regolith into a Digital Printable Material** Richa Batra, Columbia University
4:20	**Coffee Break**
	Technical Session 3 - ISRU Construction and Manufacturing Technologies (cont.)
	Session Chair: Sherry Schmidt (Deltion Innovations)
4:40	**Reaction Mechanisms in Combustible Regolith/Magnesium Mixtures** Armando Delgado, The University of Texas at El Paso
5:05	**PISCES: "PAVING" the Way to Planetary Basalt ISRU Construction - Lunar Launch/Landing Pad** John Hamilton, PISCES, University of Hawaii, Hilo
5:30	**VADERS: Voxel Advanced Digital-manufacturing for Earth and Regolith in Space** A. J. Nick, NASA Kennedy Space Center

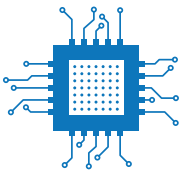
Advanced SPACE

EXPLORATION



NOVEL TECH

ON-BOARD



GROUND

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WEDNESDAY, JUNE 8, 2016

8:00 AM	**Continental Breakfast (Petroleum Hall, CSM Green Center)**
Technical Session 4 - Space Commerce & Space Policy	
Session Chair: Dale Boucher (Deltion Innovations)	
8:30	**Space Mineral Resources: Market Modeling and Propellant Demand Forecasting** Brad Blair, Newspace Analytics, LLC
8:55	**Resource Considerations for Enabling Sustainable Trans-Earth Habitation** Donald Barker, MAXD, Inc
9:20	**The Policy Context for Space Resources Development** Ian Christensen, Secure World Foundation
9:45	**ULA Cislunar 1000 Plan** George Sowers, United Launch Alliance
10:10	**Analysis and Economics of Emerging Space Industry: Lunar Resource Extraction** Andrew J. Gemer, University of Colorado, Boulder
10:35	**Coffee Break**
	Technical Session 5 – Moon
	Session Chair: Jerry Sanders (NASA Johnson Space Center)
10:55	**Google Lunar XPRIZE TEAM HAKUTO's Lunar Mission** Kyle Acierno, ispace Technologies
11:20	**Proposed Lunar Geotechnical GIS** Leon Croukamp, Stellenbosch University, South Africa
11:45	**Moon Rocks into Spacecraft LOX: Modernizing a Study and Comparing Reactions** Christopher Buelke, University of North Dakota
12:10	**Drilling for Water on the Moon** Warren Platts, Groundhog GeoScience, LLC

12:35	**Lunch (Friedhoff Hall, CSM Green Center)**
Technical Session 6 – Near Earth Asteroids	
Session Chair: Christopher Dreyer (Colorado School of Mines)	
1:35	**Assessing the Availability of Low Delta-V Targets for ISRU Development and Water Extraction** Robert Jedicke, University of Hawai`i, Honolulu
2:00	**Asteroid Provided In-Situ Supplies (APIS): Technology and Mission Architecture** Joel Sercel, TransAstra, Corp
2:25	**Preliminary Experimental Volatiles Recovery from Carbonaceous Asteroid Simulants** Egboche Unobe, Missouri University of Science and Technology
2:50	**Carbonaceous Asteroid Volatile Recovery System** Mark Berggren, Pioneer Astronautics
3:15	**Coffee Break**
	Technical Session 6 – Near Earth Asteroids (cont)
	Session Chair: Christopher Dreyer (Colorado School of Mines)
3:35	**Enabling Technologies for Asteroid Mining** Grant Bonin, Deep Space Industries, Inc
4:00	**Excavation and Volatile Analysis in Icy Asteroid Simulant** Laurent Sibille, NASA Kennedy Space Center
4:25	**Lofted Regolith Sampling of Small Bodies** Jay McMahon, University of Colorado, Boulder
4:50-6:20	**Moon and NEAs Roundtable Discussion** **Session Chairs: Angel Abbud-Madrid & Dale Boucher**
6:30	**Dinner (Friedhoff Hall, CSM Green Center)**

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ISO

THURSDAY, JUNE 9, 2016

8:00	**Continental Breakfast (Petroleum Hall, CSM Green Center)**
Technical Session 7 – ISRU Technologies and Propulsion	
Session Chair: Julie Kleinhenz (NASA Glenn Research Center)	
8:30	**Evaluation of Regolith-Based Radiation Shielding Materials** Jim Mantovani, NASA Kennedy Space Center
8:55	**Implantation of Helium into JSC-1A Lunar Regolith Simulant for Volatile Extraction System Testing** Aaron Olson, University of Wisconsin-Madison
9:20	**In-Space Propulsion and Power using Volatile Space Resources** Laurent Sibille, NASA Kennedy Space Center
9:45	**Droplet Stream Momentum Exchange as the Basis for an Extremely Efficient Solar System Transportation System** Thomas Joslyn, Omitron Corporation
10:10	**ISRU of Water for Interplanetary Steam Propulsion using Carbon Nanoparticles** Jekan Thanga, Arizona State University
10:35	**Coffee Break**
	Technical Session 8 – ISRU Technologies and Programs
	Session Chair: Jim Richard (Deltion Innovations)
10:55	**TransFormers for Ensuring Long-Term Operations in Lunar Extreme Environments** Jim Mantovani, NASA Kennedy Space Center
11:20	**Overview of Proposed ISRU Technology Development** Diane Linne, NASA Glenn Research Center
11:45	**MoonRIDERS: NASA and Hawaii's Lunar Surface Flight Experiment for Late 2017 in ISRU Dust Removal Technologies** John Hamilton, PISCES, University of Hawaii, Hilo
12:10	**South Korea Space Resources Program** Tai Sik Lee, President of Korea Institute of Civil and Building Technology

12:35	**Lunch (Friedhoff Hall, CSM Green Center)**
Technical Session 9 – Robotic Excavation and Extraction	
Session Chair: Diane Linne (NASA Glenn Research Center)	
1:35	**Thermal Vacuum Drill Testing** Dale Boucher, Deltion Innovations, Ltd
2:00	**Planetary Volatiles Extractor (PVEX) for In Situ Resource Utilization (ISRU)** Kris Zacny, Honeybee Robotics
2:25	**Design of an Excavation Robot: Regolith Advanced Surface Systems Operations Robot (RASSOR) 2.0** A. J. Nick, NASA Kennedy Space Center
2:50	**Mechanizing Extraterrestial Excavation – Transfer Potentials from the TBM Industry** Ruben Duhme, Herrenknecht AG
3:15	**Underground Resource Prospecting Using a Semi-Autonomous, Multi-Instrumented Robot** John Meyer, Colorado School of Mines
3:40	**Coffee Break**
4:00- 5:00	**General Roundtable Discussion** **Session Chairs: Angel Abbud-Madrid & Dale Boucher**

Credits

Joint Technical Steering Committee

Angel Abbud-Madrid, Colorado School of Mines
Dale Boucher, Deltion Innovations, Ltd.
Leslie Gertsch, Missouri University of Science and Technology
Stephen Mackwell, Lunar and Planetary Institute
Sherry Schmidt, Deltion Innovations, Ltd.

Session Chairs

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Dale Boucher, Deltion Innovations, Ltd.
Christopher Dreyer, Colorado School of Mines
Julie Kleinhenz, NASA Glenn Research Center
Diane Linne, NASA Glenn Research Center
Jim Richard, Deltion Innovations, Ltd.
Jerry Sanders, NASA Johnson Space Center
Sherry Schmidt, Deltion Innovations, Ltd.

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